Progress with EUV optics deposition at RIT

Yuriy Platonov, Michael Kriese, Vladimir Martynov, Raymond Crucet, Yang Li, Jim Rodriguez, Licai Jiang, Gary Fournier, Jerry Hummel

Rigaku Innovative Technologies, 1900 Taylor Rd., Auburn Hills, MI 48326, USA

Outline

- Introduction
- New deposition facility
  - ING2 parameters
  - ING2 vs ING1
  - First ML performance
- Clean/Refurb facility
  - New equipment
  - First results
- Conclusion

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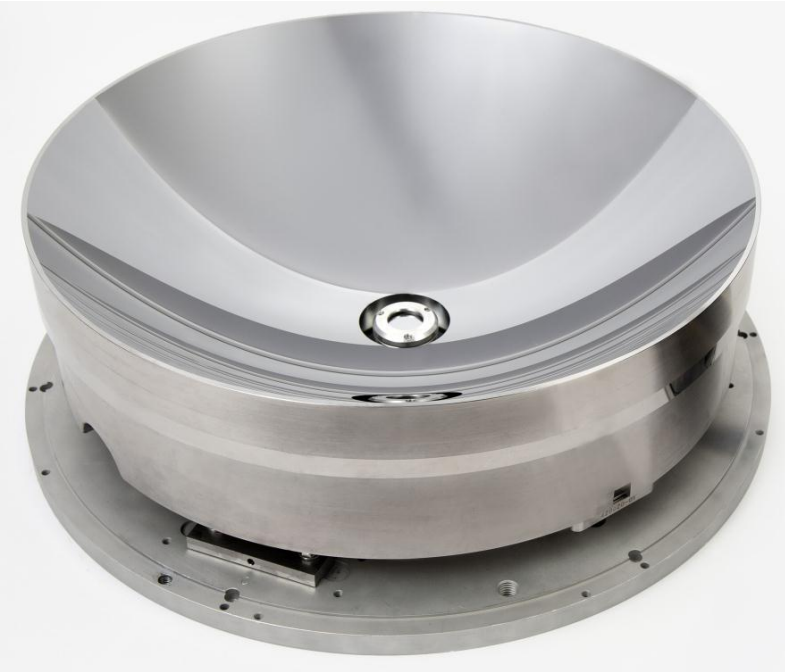
Conclusion (Dublin, Nov'13)

Collector:

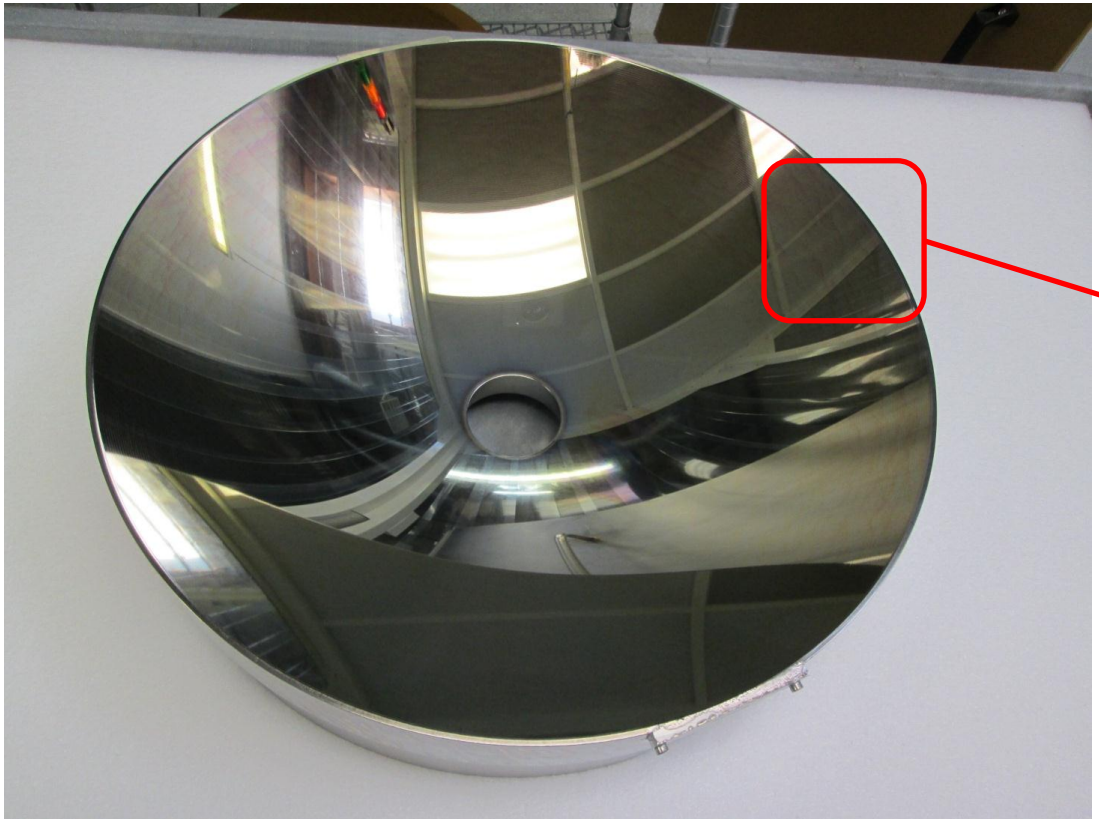
- Demo collector: ~410mm, NA ≳ 0.22
- IR Suppression (grating): 125X
- Area-weighted EUV Rp: 50.9%
- HVM-ready facility for 750mm optics (Jan-2014)

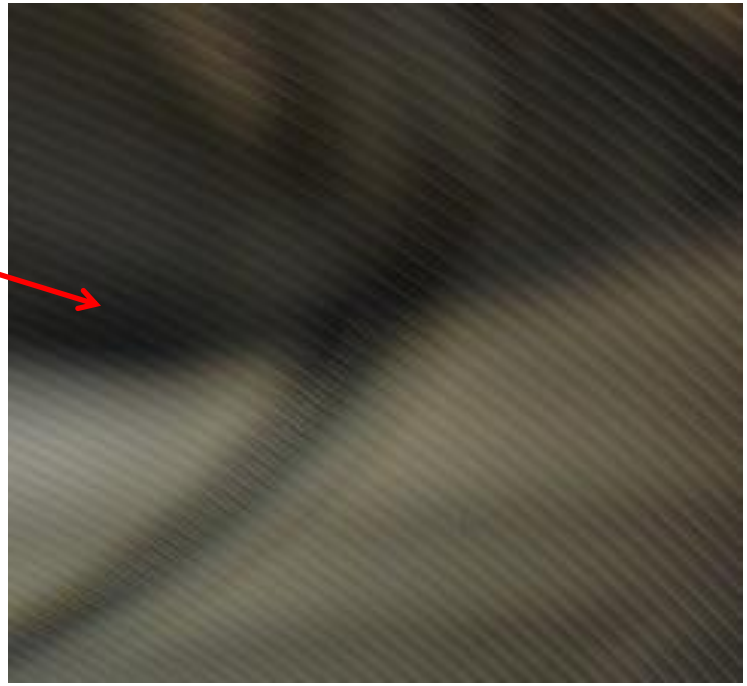


Refurbishment:

- No Buffer layer: reflectivity loss ~1% - 2% per cycle
- With a buffer layer: reflectivity loss 1.2% after 5 refurbishment cycles
- Removing multilayer top layers by Ion beam etching resulted in a large (6%-12%) loss in EUV reflectivity

Demonstration Collector: ellipsoidal ~410mm dia (NA ≳ 0.22)

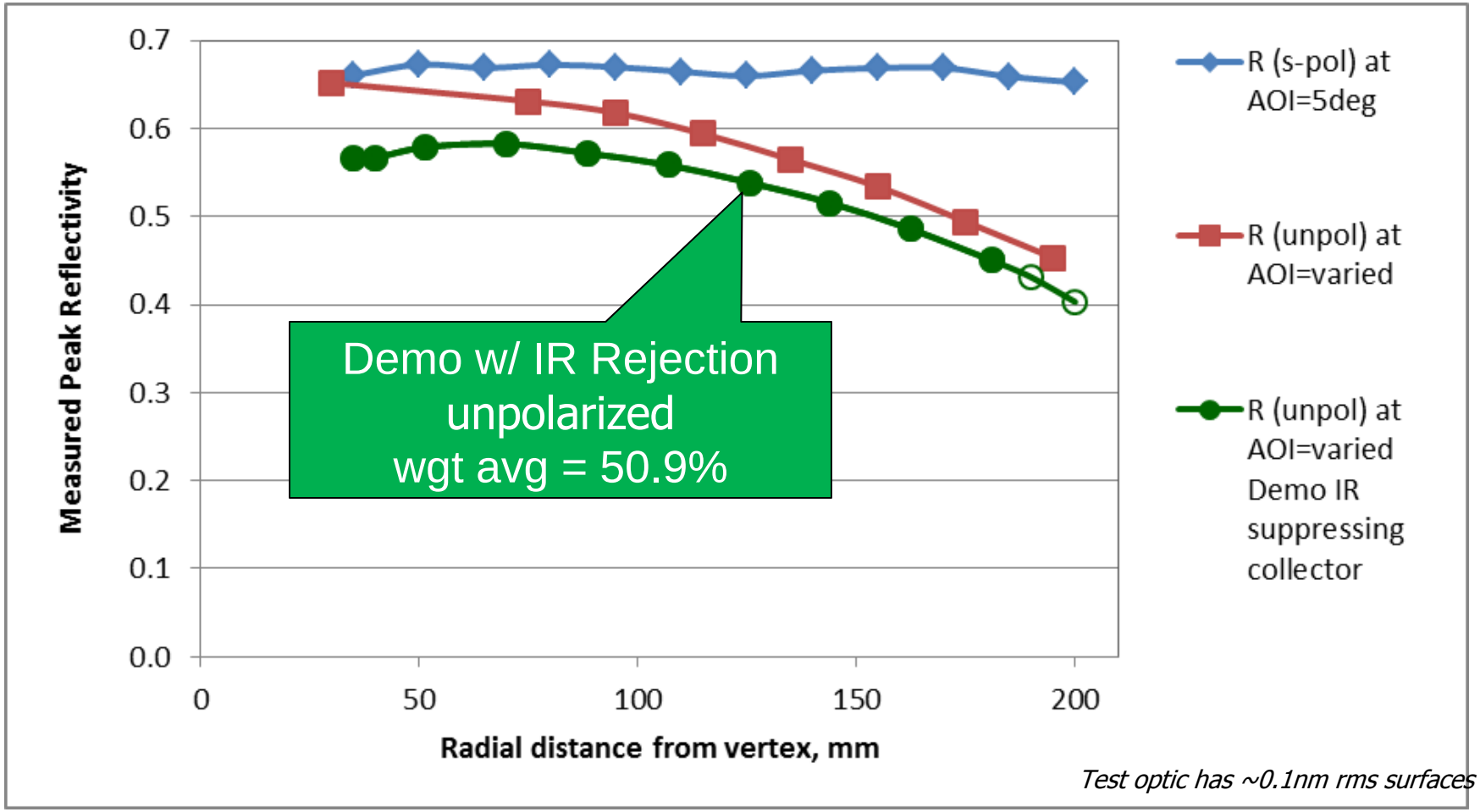




Grating structure

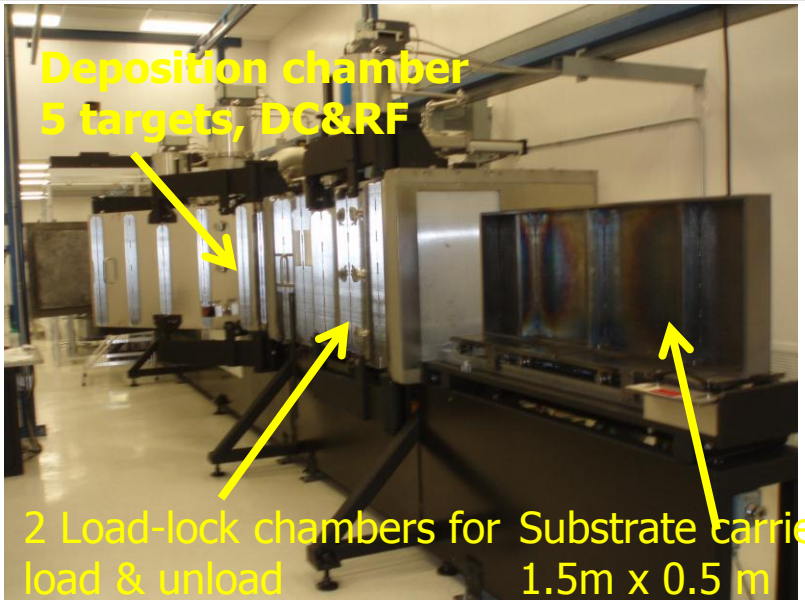
Performance at Design AOI

~5º to ~35º



Test optic has ~0.1nm rms surfaces

Current Inline Deposition Tool



Custom built system
(1997) – 17 years old

Unique for multilayer production

24/7 operation

12m long, 2m tall

- Dual Spinning Capability
  - #1: 550mm dia x 220mm thick
  - #2: 175mm dia x 35mm thick
- Mechanical
  - 0.2 mm accuracy
  - 1-100 mm/sec (±0.1%)
  - velocity profiling (6 pts/mm)

Need:

- **Larger substrates capability**
  - **~ 450 mm ➡ ~ 750 mm**
- **Better run-to-run repeatability**
  - **± 0.1 % ➡ < ± 0.05 %**
- **Reactive deposition capability**
  - **buffer & cap layers**
- **More flexibility in velocity profiling**
- **……**

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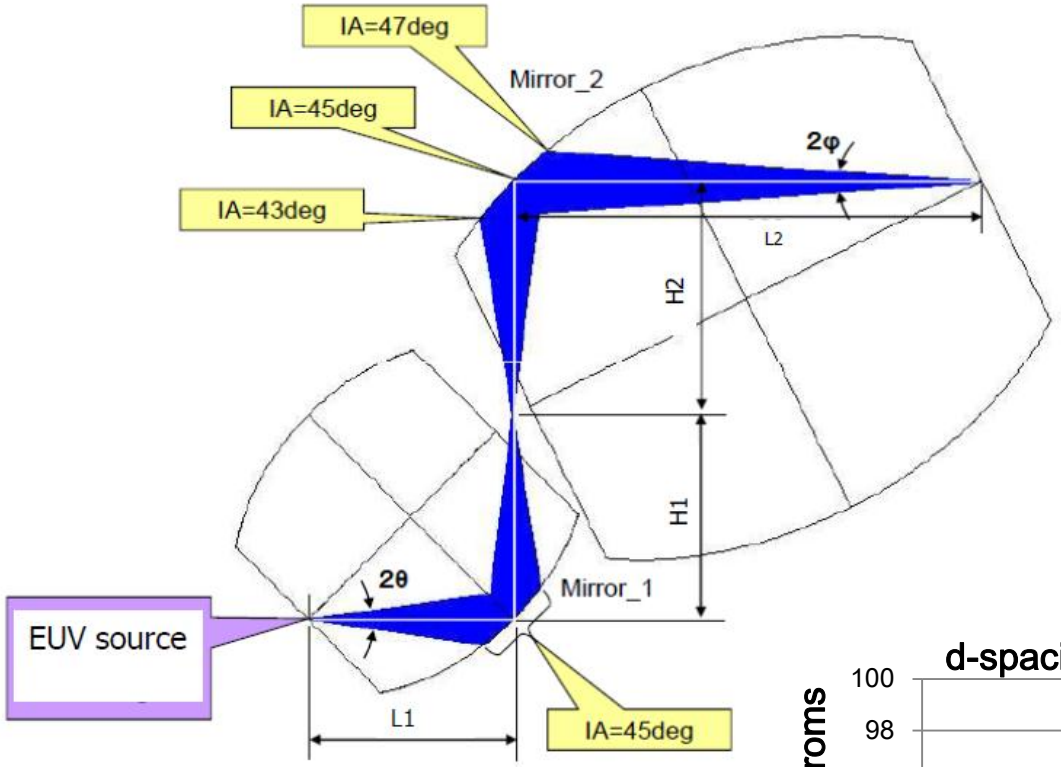
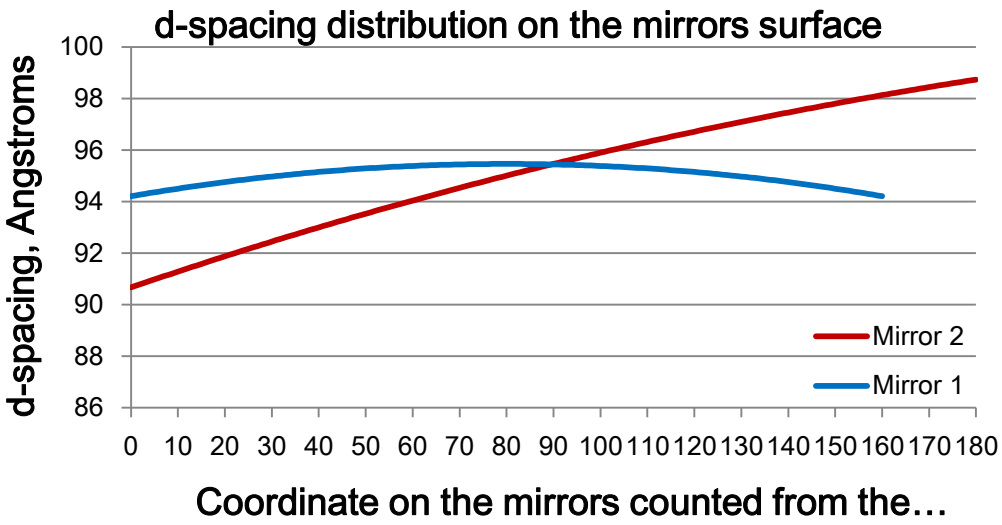
Illuminator optics



Optical layout



Tangential: graded d-spacing
Sagittal: uniform d-spacing

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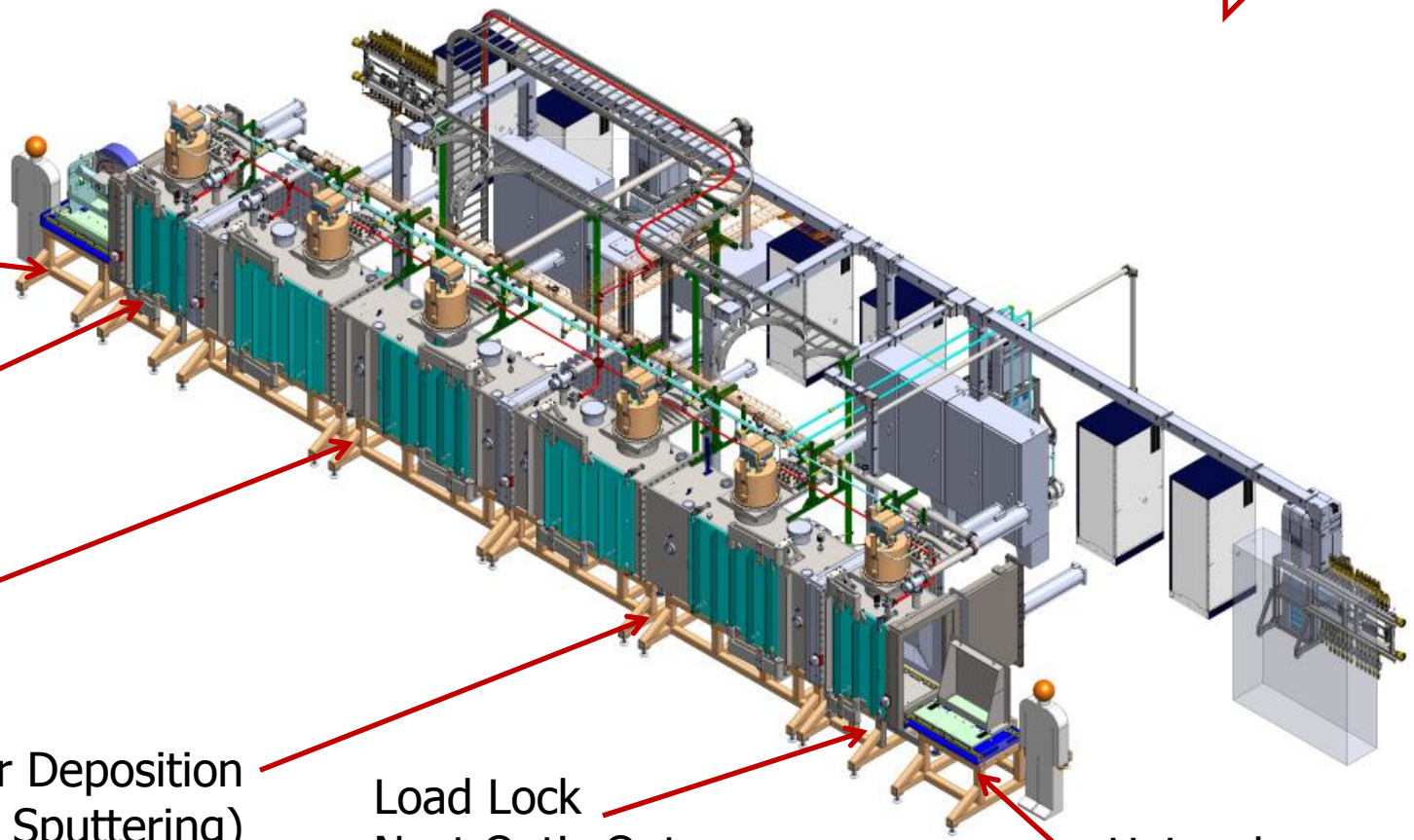
New deposition tool

- Up to 750mm DIA optics
- ~UHV, ultra stable
- Expands on 12 years operational learning our Inline1, exclusive to RIT

Production Flow – up to 4 optics simultaneously in process



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EUVL Optic Pilot Facility ~3500 ft^2

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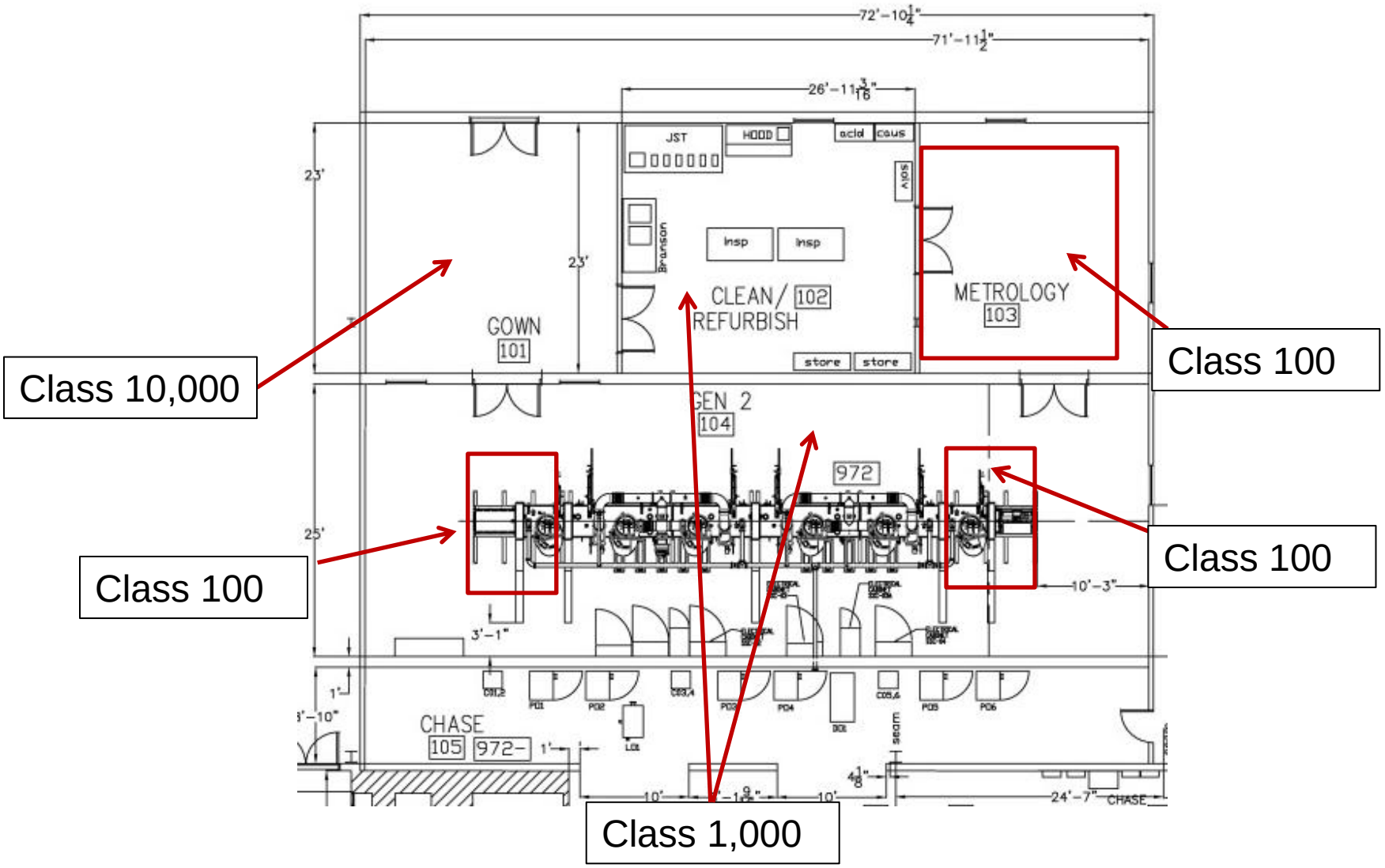
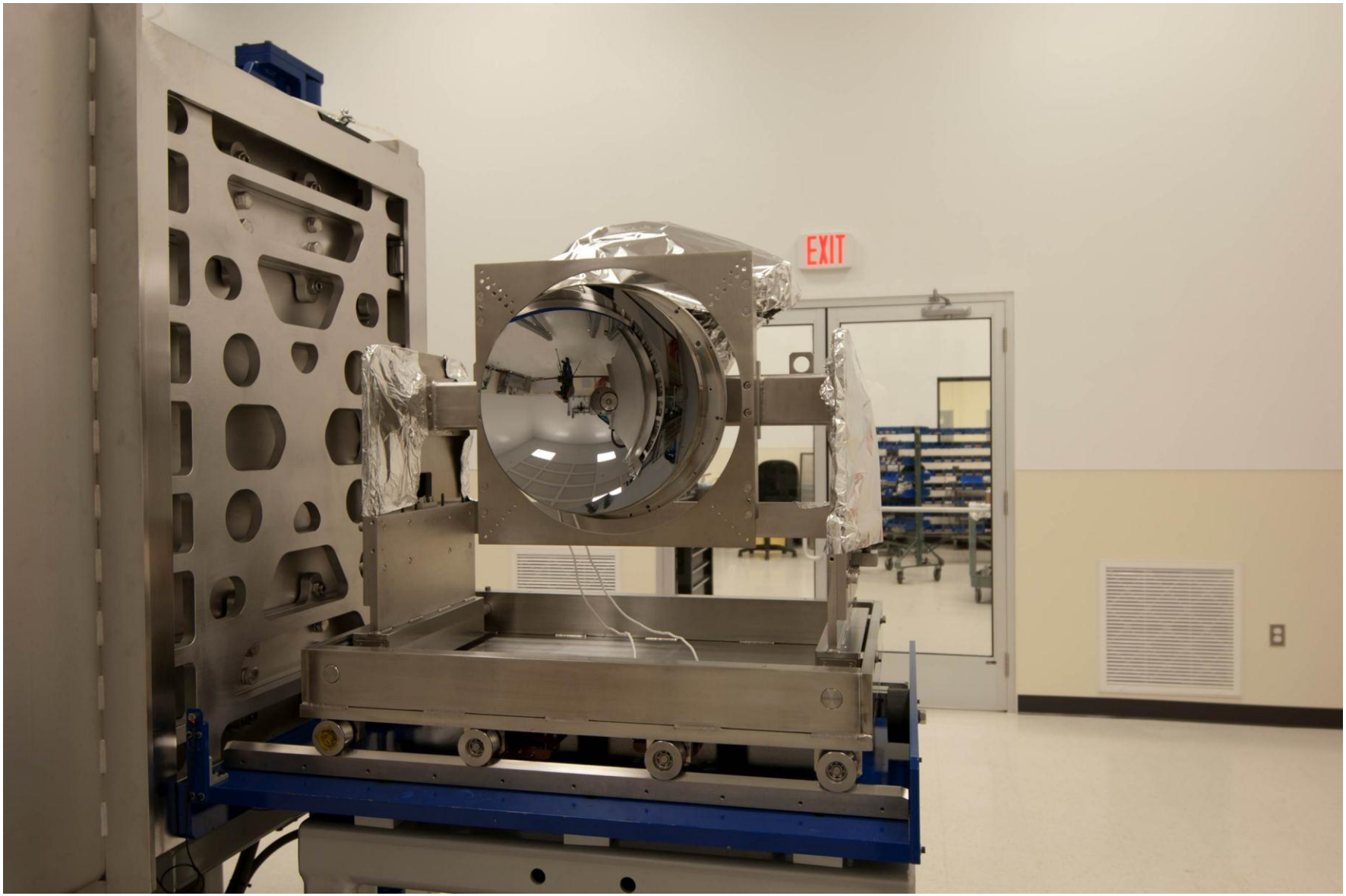


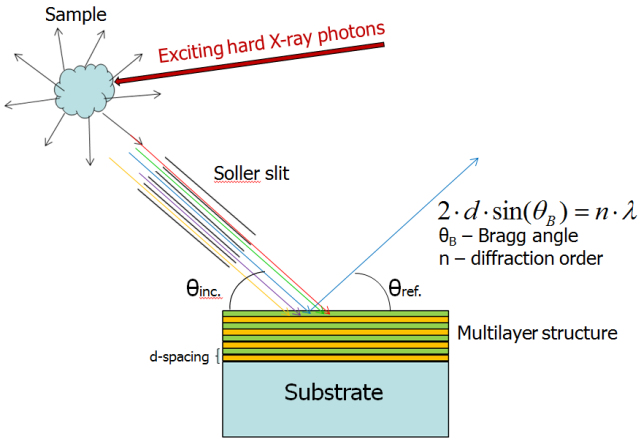
ING2 deposition system

Rotary cart for a large optics



Flat cart at ING2

Standard OVONYX™ product on ING2



OV050A product
W/Si, d=2.5nm, N=175

Ovonyx™ Multilayer Product
Vacuum Spectrometer Measurement

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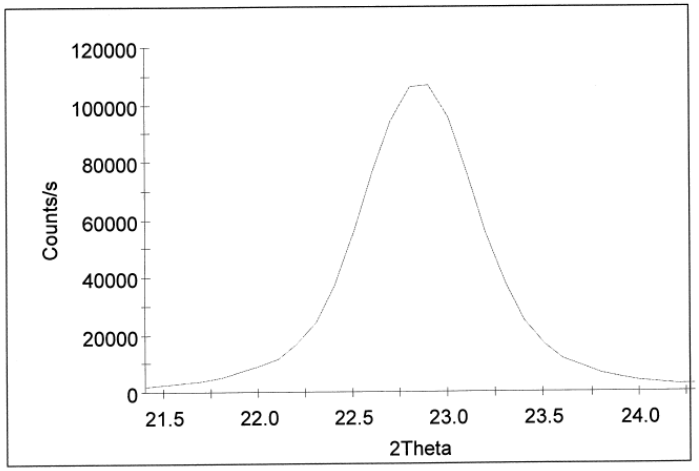
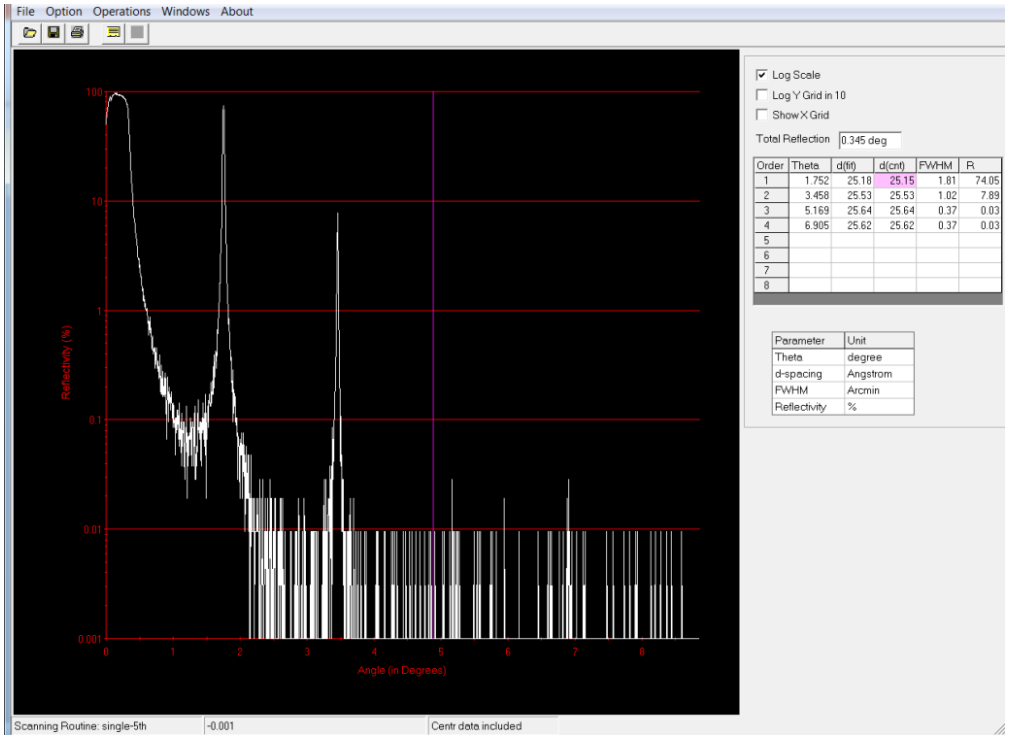
ZSX#	40089
Fluorescer	Mg_Matrix
Wavelength (nm)	0.989
Product	OV050A
Generator kV	31
Generator mA	7
Notes: Grade C	

XRO#		38843-4b		
Peak Intensity (cps)		106868.0		
FWHM (2θ)		0.723		
Peak Position (2θ)		22.85		
d-spacing (nm)		2.495		
Δλ/λ (%)		3.12		
Background	λ (nm)	(2θ)	Counts	P/B
Low Angle	n/a			
High Angle	1.104	25.57	698.0	153.10





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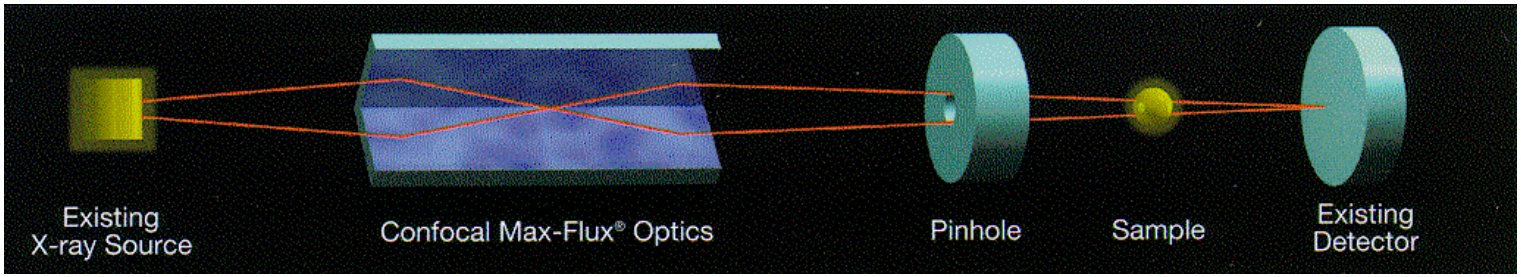
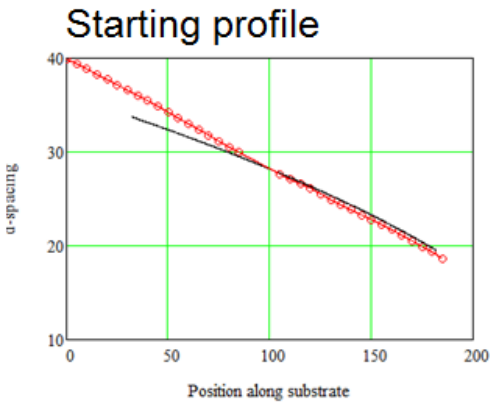
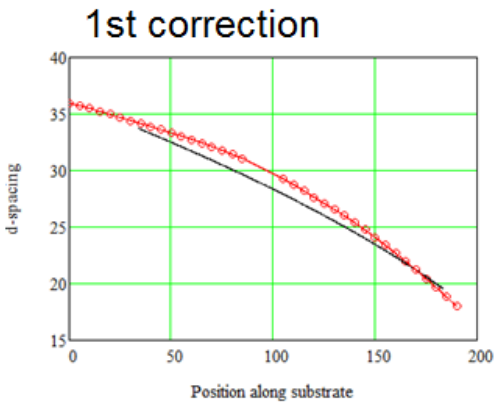
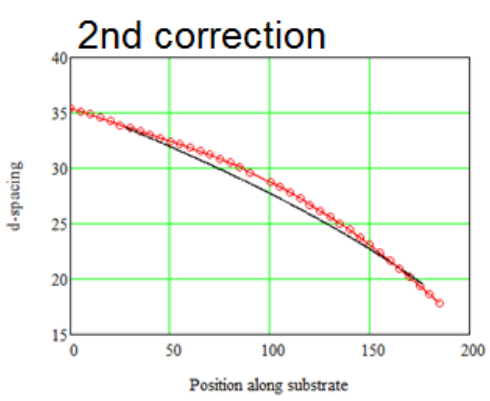
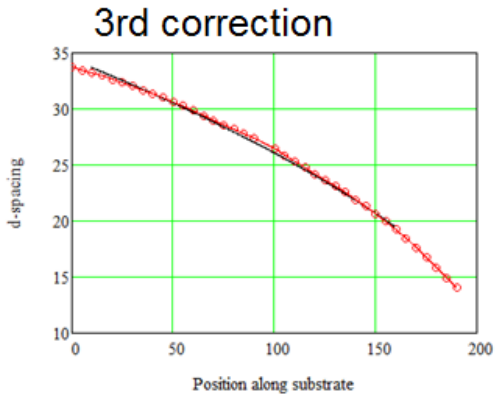
Standard MF/CMF product on ING2







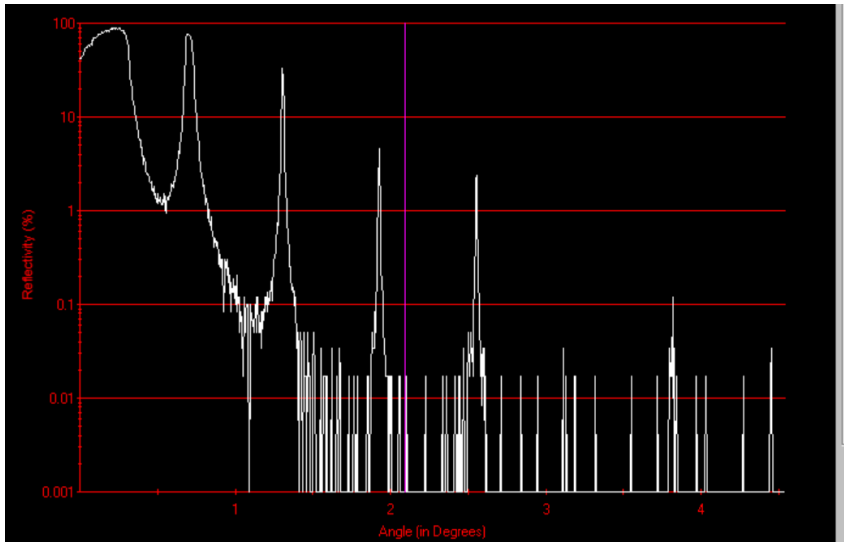




Standard VariMax™ optics

d = 1.9 nm – 3.4nm
150 mm long

EUVL coatings on ING2



Log Scale
Log Y Grid in 10
Show X Grid
Total Reflection 0.315 deg

Order	Theta	d(fit)	d(cnt)	FWHM	R
1	0.700	63.04	62.58	3.22	76.72
2	1.305	67.60	67.58	0.89	33.48
3	1.926	68.73	68.71	0.67	4.66
4	2.553	69.13	69.14	0.72	2.46
5					
6	3.817	69.40	69.40	0.58	0.13
7					
8					

Parameter	Unit
Theta	degree
d-spacing	Angstrom
FWHM	Arcmin
Reflectivity	%

One of the first Mo/Si structures deposited on ING2

No barrier, no cap layers
N=60, γ = 0.4

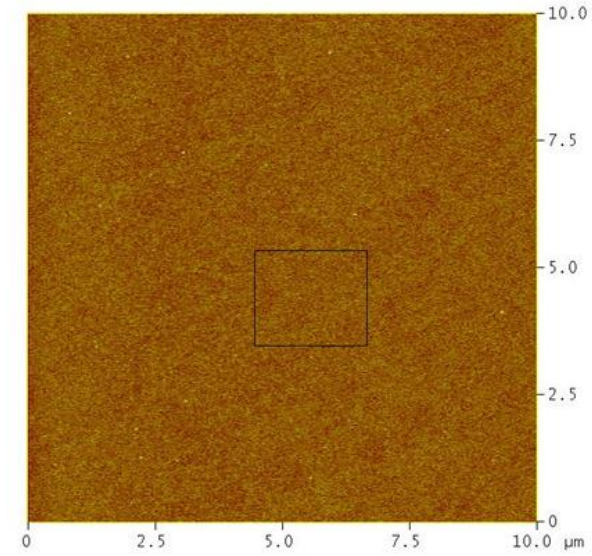
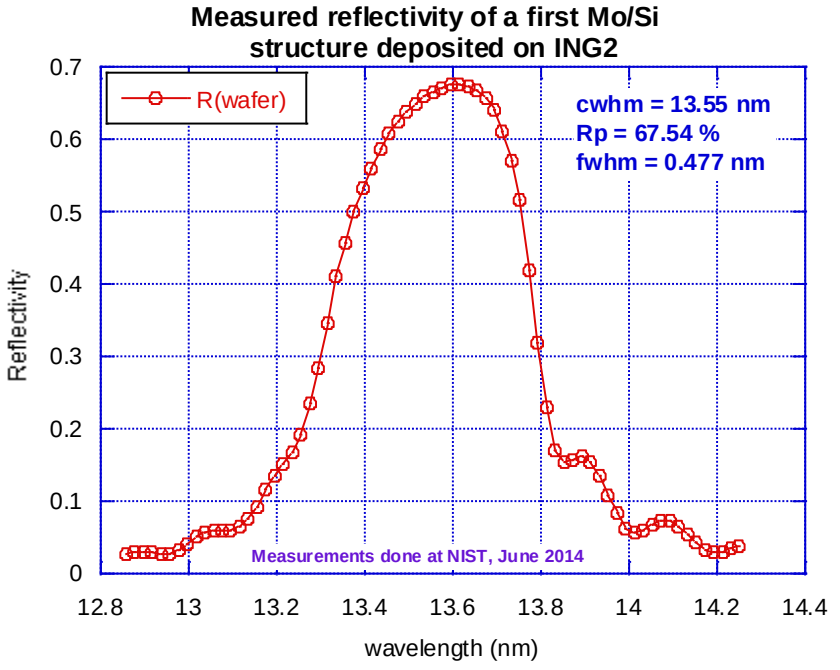


Image Statistics

Img. Rms (Rq)	0.216 nm
Img. Ra	0.171 nm
Img. Rmax	3.739 nm

Box Statistics

Rms (Rq)	0.210 nm
Mean roughness (Ra)	0.167 nm
Max height (Rmax)	1.498 nm
Max peak ht (Rp)	
Av max ht (Rpm)	
Max depth (Rv)	
Av max depth (Rvm)	
Box x dimension	2.211 µm
Box y dimension	1.879 µm



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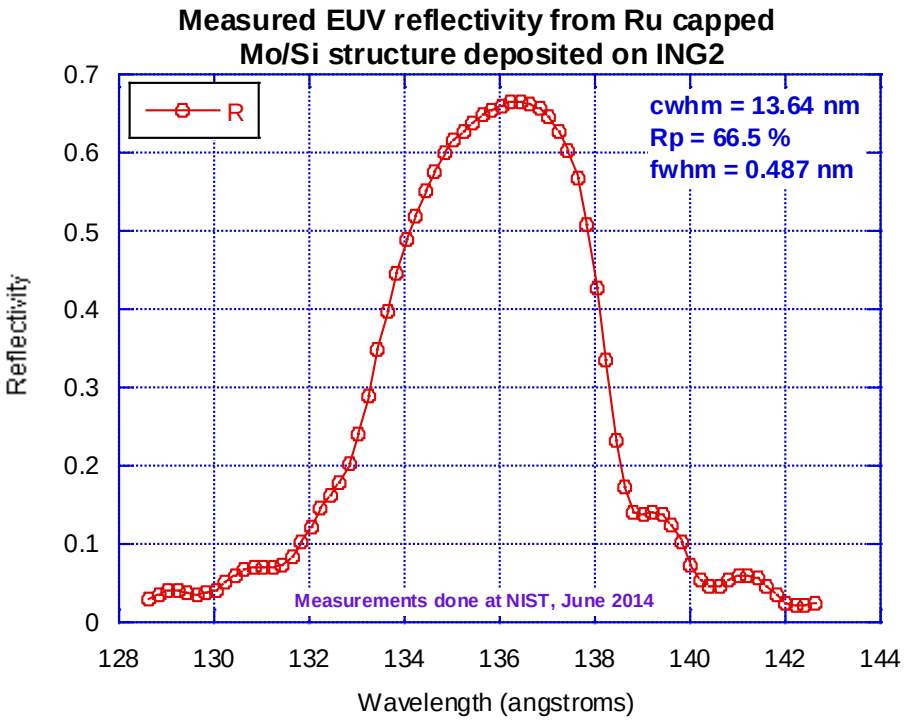
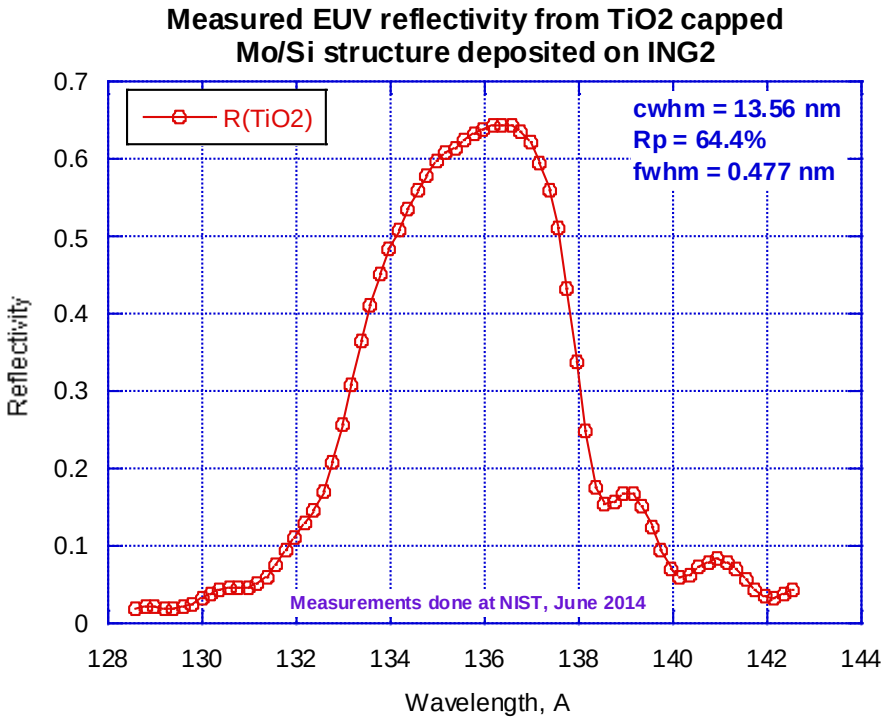
Capped Mo/Si from ING2





1% lower than uncapped

2% lower than uncapped

Parameters: ING2 vs ING1

Parameter	Inline G2	Inline G1
Home position	≤ 0.05mm	± 0.2mm
Velocity vs. position repeatability	≤ 0.05%	~ 5x worse
Pump down time	24 hours	48 hours
Base pressure	$1x10^{-8}$ Torr	$1x10^{-7}$ Torr
Target size	30 inches	20 inches
Max. speed of carrier	150 mm/s	100 mm/s
Max. acceleration	150 mm/s^2	10 mm/s^2
Reactive sputtering	yes	limited

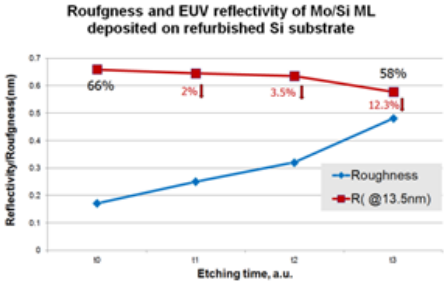
Major Advantages

- Much improved vacuum with advanced pumping systems, heaters and polycolds
- Much improved motion control systems for higher accuracy and larger range in position, speed and acceleration
- Fully equipped with multiple gas feeding systems
- Larger targets and full height ion milling capabilities
- Continued operation with load lock systems for high volume production
- Large capacity

EUVL Optics Refurbishment

No Buffer layer

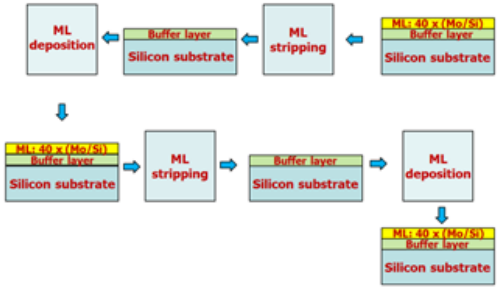
Mo/Si multilayer structure with a cap layer deposited on Si substrate – no buffer (current M1-M5 mirrors delivered to EDEC)

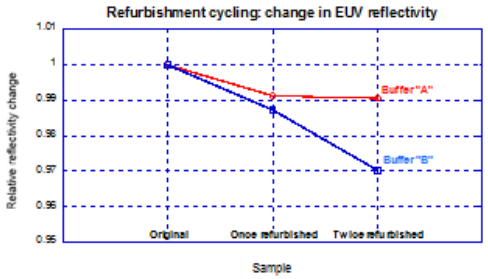


~ 2% loss per cycle with no buffer layer

Introducing a buffer layer

(2 cycles - original coating has no buffer layer)



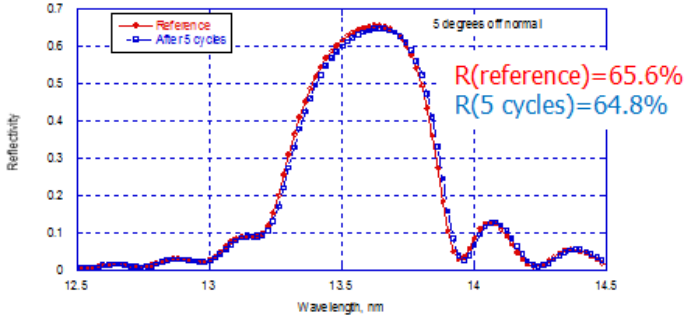


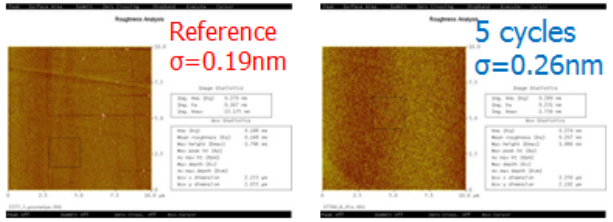
~ 1.9% after 2nd cycle with a buffer layer

(no buffer layer in original coating)

5 cycles with a buffer layer

(original coating has a buffer layer)_





~ 1.2% loss after 5 refurbishment cycles

(original coating has a buffer layer)

Used etching station

Etch baths

- Needed
  - Larger size capability
  - Better agitation
  - Better temperature control
  - More baths for multi steps etch-cleaning processes
  - Better safety

Reliable and repeatable results

New etch/cleaning station

New Etch/Clean system

- 7 Teflon baths
- Up to 250 mm optics
- Programmable process
- Temperature up to 140°C
- High frequency ultrasonic
- Recirculating pumping

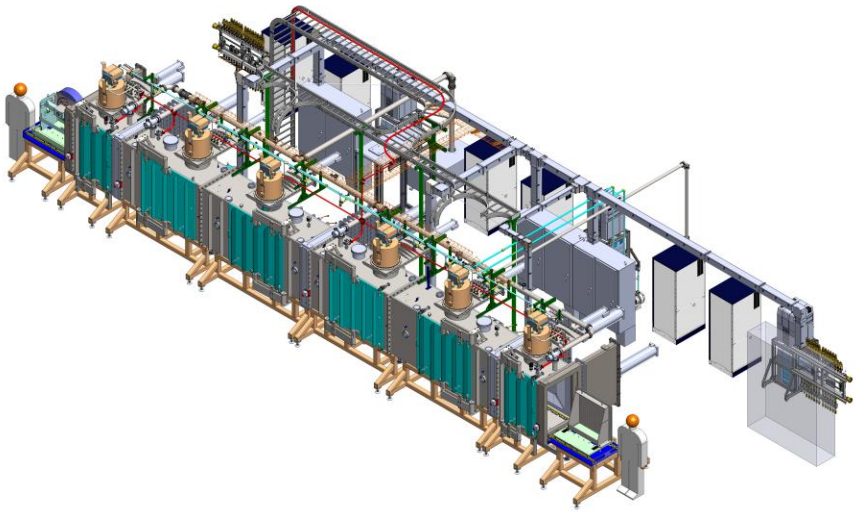
Branson's cleaning system

- 2 stainless steel baths
- Up to 450 mm optics
- Ultrasonic
- Recirculating pumping
- Temperature up to 90°C

Conclusion

New HVM Deposition Facility:

- 750 mm optics deposition capability
- Improved motion control
- Multi gas feeding
- Separate reactive deposition chamber
- High volume production



New Clean / Refurbishment facility:

- Larger sizes (up to 250 mm optics)
- Better agitation with recirculating pumping
- High frequency ultrasonic
- Better temperature control
- Programmable refurb / cleaning process

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Acknowledgement

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Thank you

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